A COMPARISON OF THE EFFICIENCY OF FOUR STYLES OF BREAST STROKE

by

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A Thesis Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Master of Science in Physical Education

Greensboro
June, 1965

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ZEH, BRENDA SUE. A Comparison of the Efficiency of Four Styles of Breast Stroke. (1965) Directed by: Dr. Rosemary McGee. p. 81.

This study was conducted for the purpose of determining the relative efficiency of four styles of breast stroke for use by recreational swimmers. Four intermediate swimming classes, composed of fifty-three freshman and sophomore women at the University of North Carolina at Greensboro, were taught four different breast stroke styles. Combinations of two arm styles, a horizontal pull and a diagonal pull, and two leg styles, a wedge kick and a whip kick, were used.

A skill rating was administered to each class at the end of six weeks of instruction as a means of showing the similarity of the classes. The efficiency of the strokes was considered in terms of power and oxygen uptake. Force was measured by the distance covered in five complete breast strokes. Increased oxygen consumption over the sitting resting rate was measured following a fifty yard breast stroke swim.

The data collected were treated statistically to determine the objectivity of the skill rating, the reliability of the power test and the significance of differences between the groups on skill rating, power and oxygen uptake.

The following results were obtained.

1. The skill rating was considered sufficiently objective for use as a measure of similarity of the classes.
2. The skill levels of the classes were similar.
3. The power test was reliable.
4. Differences were apparent in the power measures of the classes.

5. Class 4, using a horizontal pull and a wedge kick, produced power scores significantly superior to each of the other classes.

6. Conclusions were not drawn from the oxygen uptake data because of the degree of unreliability apparent in the test.

ACKNOWLEDGMENTS

The writer wishes to express her sincere appreciation to Dr. Rosemary McGee for her guidance and cheerful encouragement throughout the course of this study.

Appreciation is extended to Margaret Duncan, Shirley Flynn, Sharon Stroble, and Katherine Carsey for their assistance as instructors and judges.

Acknowledgment is made to the students of the University of North Carolina at Greensboro, who were enrolled in the intermediate swimming classes. Their willingness to participate and their cooperation made this study possible.

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CHAPTER I

INTRODUCTION

Man is not by nature at ease in the water. His physical structure and habits make him more at home on land. His respiratory functioning demands that he be above the surface in order to breathe. His upright posture and specific gravity make it difficult for him to stay above water. His body temperature makes it difficult for him to stay in the water for long periods of time. His body shape is not conducive to either bouyancy or locomotion in the water. Even the movements which he has developed for use on land are of very little use to him in the water.

Yet, the human body is so adaptable that, when coupled with the inventive mind of man, movement patterns which are effective in water have been discovered and developed. Ancient wall reliefs, large stone bas-reliefs and coins have been found which indicate that the early civilizations had a knowledge of swimming movements. There are records of an ancient Egyptian nobleman which show that children were being taught to swim in the River Nile as many as 4,000 years ago[43].

The American Red Cross[2] holds the belief, based on analysis of the information mentioned above, that the first swimming stroke ever used was a type of paddling stroke on the front which they call the "human stroke." This is similar to the "dog paddle" used by uninstructed swimmers today. Travelers among primitive races in warm climates reported the evolution of this stroke into an overhand stroke[(2)]. It is possible that the added speed was a factor in this adaptation.

However, not until the sixteenth century is there any written record of the form of stroke used in swimming. The first book about swimming, written by Nicholaus Wynman, describes a stroke very similar to the breast stroke of today[(3)]. A later book, written by Thevenot, who was considered the authority on swimming for over a century, describes the arm action like oars in rowing a boat and the leg action as similar to the kick of a frog[(3)]. The breast stroke remained the most popular stroke well into the nineteenth century. It is the stroke which was used by Captain Matthew Webb when he swam the English Channel in 1875[(31)]. Soon thereafter the side stroke gained popularity, possibly as a means of keeping the face out of the water[(34)]. The evolution of the swimming strokes in Europe and America from that point on was brought about primarily because of a desire for greater speed. They appeared, in order of succession, as the trudgen stroke, Australian crawl, trudgen crawl and the American crawl. It was not until the early twentieth century that the crawl strokes were fully developed in Europe and America[(10)].

A review of history indicates that man first learned to swim for military and survival reasons[(44)]. These are still considered important reasons for swimming today. Swimming is considered a valuable skill for the men in the armed forces. The "Learn to Swim" campaign following World War II emphasized the safety aspects of swimming. In more recent years, the fitness movement has placed more importance on the physiological contributions of swimming. Swimming helps to develop muscle tone, promotes respiratory and circulatory development and increases strength and endurance[16].

In modern times water sports and swimming itself have become primarily recreational activities. The recent increase in popularity of boating, water skiing, skin and scuba diving and other activities has made a knowledge of swimming an even more valuable possession for the average person.

The great majority of swimmers do not regard their swimming skill as competitive sport or a dramatic art but simply as a recreational activity for their own enjoyment. Few of these swimmers are really skillful. It would seem wise then, for early instruction to include a stroke designed to provide the greatest measure of safety and enjoyment.

The breast stroke appears to fulfill the requirements for such a stroke. Ryan and Ryan[43] consider the breast stroke to be the most useful of all strokes. The American Red Cross refers to it as ". . . one of the most valuable and dependable styles of swimming in the swimmer's equipment."[2:110] It is well suited to distance swimming because of its stability, balance of power in the arms and legs, long glide and adaptability. It is a highly social stroke because it offers opportunity for conversation and observation. It is closely associated with other swimming skills such as underwater swimming, surface diving, elementary back stroke, treading water and inverted breast stroke. It is excellent for emergency swimming in rough water and swimming while fully clothed. Lukens states that the, "breast stroke is the most important stroke the pupil will learn: . . ."(33:9)

However, a comparison of descriptions of the movements involved in the breast stroke show that several different opinions exist as to its proper execution. If the stroke is to be used by the average swimmer for purposes of recreation and safety, the form needs to be one capable of enabling the swimmer to cover relatively long distances with a minimum of fatigue. This study was concerned with comparing various patterns of the breast stroke to see if one is more efficient in terms of power achieved and effort expended.

CHAPTER II

STATEMENT OF PROBLEM

I. PURPOSE

This study was conducted for the purpose of comparing four styles of breast stroke. The four styles were combinations of two types of arm strokes and two types of leg strokes used in swimming the breast stroke. The relative amount of force and oxygen uptake were examined to determine the efficiency of each combined stroke for use by recreational swimmers of average skill. The subjects were freshmen and sophomore women enrolled in intermediate swimming classes at the University of North Carolina at Greensboro.

II. DEFINITION OF TERMS

Efficiency

Efficiency was considered in terms of force and oxygen consumption. Force was measured by the distance covered in five complete breast strokes. The increased uptake of oxygen was measured following the breast stroke performance. The stroke enabling the swimmer to cover the greatest distance with the least expenditure of energy was considered the most efficient.

Wedge Kick

Phase 1. As the knees bend they spread outward and the feet remain together. The legs are in a horizontal plane parallel to the surface.

Phase 2. The legs straighten at the knees spreading the feet apart. The soles press against the water.

Phase 3. The legs draw together with the knees straight.

Whip Kick

Phase 1. The knees bend downward as the feet are drawn up over them. Both the knees and feet are in line with the hips.

Phase 2. The knees remain stationary as the feet move outward and backward in an arc.

Phase 3. The legs draw together with legs straight.

Horizontal Pull

Phase 1. The arms pull outward and only slightly downward (not more than six inches) with the elbows straight.

Phase 2. Just before the arms reach shoulder level the elbows bend to draw the arms and hands in toward the body.

Phase 3. The arms extend to a position in front of the head.

Diagonal Pull

Phase 1. The elbows bend as the arms pull so that the hands are directly under the elbows when the upper arms have reached shoulder level.

Phase 2. The hands lead up and under the chest and the upper arms follow in to the sides.

Phase 3. The arms extend to a position in front of the head.

A more complete analysis of the strokes may be found in the Appendix.

CHAPTER III

REVIEW OF LITERATURE

The breast stroke has undergone many changes in style throughout the long history of swimming. At the present time, there are several styles advocated by swimming authorities. In view of the recent increases in emphasis on water activities as a popular recreational activity, and the many advantages of the breast stroke as a recreational stroke, this study was undertaken to determine a style of breast stroke best suited to the needs of the average swimmer. A survey of various descriptions of the form of the breast stroke was made to determine the nature of the actions advocated by various writers. The leg stroke, arm stroke and coordination were each considered. The methods of analyzing swimming strokes which have been used in previous studies, and the factual information gleaned from the studies have been reviewed.

I. ANALYSIS OF STROKE

A review of the literature of swimming will show that there has always been some disagreement concerning the proper action in swimming the breast stroke. The disagreement is partially due to a lack of uniformity in terminology. Words such as bend, fold, and draw, which have been used to describe the first recovery movement of the legs, have various connotations which can lead to faulty interpretation. This is also true of words like drift, swing, thrust, snap and pull. The exact positions meant by backward, outward, down, around and circular are also hard to determine.

Not all of the controversy is due to terminology. Certain stages of development can be determined by a chronological survey of the strokes. Some definite changes have taken place during the history of the breast stroke. Although trends can be traced through history, no one style was unanimously adopted by all writers during any single period.

Development of Leg Stroke

It was the common practice of early writers to refer students to the study of frogs as an aid in learning the breast stroke kick. Wynman, the first author of a book on swimming, said that the feet are like oars; and later he said, "watch how frogs swim with their hind feet."(2) This suggested, in the earlier case, the use of the inside of the legs, and in the later, the use of the soles of the feet for power. Benjamin Franklin, (2) in 1773, stated that he observed the insides of the feet and the arches were used. A little later GutsMuth(2) said the outsides of the legs pressed against the water. Finally, in 1818, Frost spoke out against the frog pattern when he said, ". . . if you would be a swimmer, you must imitate the action of a frog, is founded on a gross mistake; . . ."(19:10) In spite of his statement, the frog is still used as an example today and the kick is commonly referred to as the "frog kick."

The description of the kick by Frost, which followed his statement against the frog example, was quite detailed with the exception of the first movement.

> The first part of the action of the legs, is to draw them in as high as possible; when a turn of the ankle must be made, so as to cause the soles of the feet to incline outward, the knees at the same time inclining inward; the feet must now be struck out as widely from each other as can be done, to the extent of the legs. In the next place, the legs must be brought down briskly, until the feet come nearly together.
>
> If the turn of the ancle [ankle] and the knees here described, should be neglected to be made, considerable loss will be sustained, as the feet cannot be thrown out advantageously with it.(19:11-12)

Sinclair and Henry, who published another of the earlier sources in 1893, also included a detailed explanation of the kick. The first movement is clearer and the second appears to be somewhat different from that described by Frost.

> 1. Turn the toes outward to the right and left respectively with the heels nearly touching. Draw up the feet gently towards the body somewhat above the level of the back, and as they near the body separate the feet a few inches. When drawn up, the soles of the feet should be facing upward and be just below the surface, whilst the knees should be turned outward to the right and left, and not drawn up under the body.
>
> 2. To develop the next movement the legs must be smartly kicked in the outward direction to the thighs; and in kicking out, the lower part of the leg from the knee joint to the toes should be swept with a vigorous downward and arched or rounded movement from the knees, the water being slashed with the whole of the front of the foot as the leg is being straightened. By keeping the ankles loose a flip will be imparted to the foot as the legs are being brought to the third position.
>
> 3. As soon as the legs have been straightened, continue the stroke without interruption by closing the legs with vigor until they nearly touch each other in line with the body, preparatory to bringing them up into the first position.(46:71-73)

However, until the mid 1930's, the majority of descriptions of the breast stroke leg action followed the example of Frost. Kellermann(30), who wrote one hundred years after Frost, agreed with him in all the primary movements. Sheffield and Sheffield[45], who published a book in 1927, also agreed with the above authors with the exception of the width of the opening of the legs on the second movement. Other authors who suggested similar strokes were Fletcher[15], Dalton[11], Smith[49], McGillvray[37], Manley[35], and Brewster[6].

Changes became more pronounced in the leg action of the breast stroke in the 1930's. When the butterfly breast stroke was introduced in 1934, the kick became modified to fit the new arm stroke and was later found to be helpful in lowering competitive times on the orthodox stroke[28]. The breast stroke kick was in the transition phase during the years between 1935 and 1950. The writing of that time was of a very general nature; often vague. An example is this description from a book by Hamilton. "The knees go outward as they bend and draw the feet upward with the soles together. The legs are separated to the sides in a V-shape, then pulled together with extended knees."[22:36] Whitford[54], Reichart and Brauns[39], Lawson and Mader[32], Francis[18], Riggen[40], Hedges[25], and Forsyth[17] gave descriptions quite similar to the one by Hamilton. Kiphuth was a little more thorough in his writing in 1942, but he did not take a stand for one style.

> The kick may be roughly classified as either a whip or a thrust kick. The recovery is effected by drawing up the legs with the heels fairly close together and with the knees flexed, with either a narrow or wide opening sideward. From this position the legs may be thrust backward and together or they may whip from the knee outward and together.[31:77-78]

There were three notable exceptions to the general pattern during that period. The American Red Cross book, published in 1938, included a detailed analysis of the kick.

> To begin the stroke the feet are drawn toward the body as the knees are extended sideward until the point of maximum bend is almost reached. At this point, the knees are rotated inward as the feet and lower legs are slued until they extend sideward. Immediately, as a continuation of this rotating movement, the legs are brought together until they resume the starting position.(2:85)

The Boy Scout manual, published in the same year, described a similar stroke. The more general nature of the description, especially on the first movement, made it difficult to say that they were exactly the same stroke. The description of the knee rotation is the most notable difference.

> . . . bring the heels up toward the buttocks. Do not draw the knees too much in under the body. At the finish of the draw the toes are turned outward to allow the inside of the foot and lower leg to catch the water. From this position the leg drive starts. The motion is a push down and backward with both legs, at the same time spreading them apart. As soon as the legs are straight they are brought together with a snap, thus reaching the starting position.(5:58)

The writing of Ann Avery Smith in 1930 was perhaps the closest to a scientific description of the movements because of her use of kinesiological terms. The description of the knee rotation was similar to the American Red Cross stroke. "The knees remain the same distance apart. By means of an inward rotation at the hip joint the heels are swung about a foot apart."(48:150)

From 1948 to 1960 writers took an individual stand regarding the style of kick each recommended. In general, the knee separation was narrower and the feet were apart in the recovery, the second phase did not extend the legs so much to the side, and the final stage was a strong whipping around and together. Although most were modifications of one of the above strokes rather than the older style, each stroke was slightly different from any of the others.

Madders stated, "The modern tendency is to use a comparatively narrow knee spread in the diamond position, the knees taking a more downward course as they bend."(34:67) Brown also stated that the knees were much lower than the feet, but he differed in the second movement of the stroke when he said, "separate the feet, toes turned out, and move the knees inward."(7:104-5) Ryan and Ryan advocated a very narrow knee spread on the recovery when they said, "Bend the knees and bring both heels straight up until they are over your knees." They then said to "open them wide" on the second movement.(43:61) Lukens(33) said the feet and knees should be the same distance apart on the recovery and did not recommend spreading the knees farther on the second movement. Smith(49) suggested bending the knees with the feet apart and flexing the hips only a little. Shaw, Troester and Gabrielsen(44) were nearer the older styles but they did recommend that the heels ". . . move apart to a distance of about 10 to 12 inches."(44:286)

From 1960 to 1963 the trend appeared to return to the older style typical of Frost. The knees were spread to the outside on the recovery; and the second phase, while a little narrower than the Frost style, was a straightening of the knees rather than the circular thrust described in the 1950's. The emphasis of the movement was generally in the push with the soles of the feet. Although each author described a stroke just a little different from the others, McAllister's book, published in 1961, is typical of the writing.

1. Rotate the knees outward while bending them upward.
2. Straighten the legs forcefully, pushing the soles of the feet against the water.
3. Continue the stroke by forcing the legs together.

4. Hold for a moment for a good glide.
5. Keep the head up and breathe naturally with the mouth open.
6. Keep the shoulders under water. (36:49)

Other authors who described the same style kick were Burke and Smith[8], Garstang[20], Robertson and Harlan[41], Russo, Jordan and Matheson[42], and Higgens, Barr and Grady[26].

Again there are several notable exceptions to the general pattern. Vannier and Poindexter, in 1960, and Juba[28], in 1961, presented a similar stroke.

> The leg action begins from extension, knees draw toward the body, dropping slightly and separating easily. Feet flex outward and reach away from the body. The power drive is accomplished by a whipping sweep out and backward with ankles and feet leading to an extension for riding the glide. (53:196)

Another exception was made by Armbruster, Allen and Billingsley[3]. They carefully described three different styles of the leg stroke. They recommended the "wide whiplash kick" for the short legged swimmer. The newer kick was suggested for the longer legged swimmer with long broad feet. The legs were drawn up toward the pelvis instead of spread and a screw type kick, made with the forelegs followed by extension of the feet, was used for the power phase. For the swimmer with a medium build, they recommended a combination of the two kicks which consisted of a limited spread of the knees and a combination of thrust and squeeze action on the power phase. This was the one recommended for general use by the average swimmers.

Development of the Arm Stroke

The development of the arm action of the breast stroke can not be traced through history as easily as can the leg stroke. There are differences of opinion among the authors concerning the position of the hands, the length of the pull, the depth of the pull and the action of the elbows on the recovery. All of the various combinations of the styles have been in use through the complete history of the stroke with no apparent progression from one to another.

One of the earliest of the authors, Thévenot, included the basic elements of the stroke, but so many of the details were omitted that it is difficult to determine just which of the many styles was in use at that time. Thévenot instructed the swimmer to, ". . . stroke out your arms forwards, and spread them open, then draw them in again toward your Breast; . . ."(51:16)

As early as 1818, Frost gave a very complete description with much attention to the various positions of the hands.

> The first elevation of the hands is found by raising the fingers higher than the thick of the hands, by three or four inches at the ends; the second elevation of the hands is made by raising the outer edges, or little finger side, two or three inches higher than the inner edge, or thumb side; and as the outer stroke is performed this elevation must be a little increased.(19:7)

The first elevation was to be used during the extending of the arms forward from the breast. The second elevation was for the pulling phase, for power(19).

One of the more complete of the earlier descriptions was done by Sinclair and Henry in 1893.

> 1. Draw the elbows nearly to the side, at the same time bringing the forearms and hands up to the front of the chest with the palms of the hands downwards near to the surface of the water, fingers extended and closed, forefingers and thumbs nearly touching.

> 2. Push the hands forward directly in front of you till the arms are at their full extent, still keeping the hands about two or three inches below the surface of the water, and pause or lay on slightly before beginning the next movement.
> 3. Turn the palms of the hands slightly outwards and take a backward sweeping stroke, and continue the pressure until the hands and arms are brought nearly to a right angle with the body in line with the shoulder. Then gently fold the arms back into first position. As soon as the pressure of the backward sweeping stroke ceases the hands should be immediately flattened.[46:75-6]

Fletcher[15], in 1899, described a very similar stroke.

In 1918, Handley described a stroke which he claimed was a new stroke adopted by leading swimmers but different from the stroke commonly taught at that time. Handley said, "The arms are no longer swept back close to the surface until at right angles to the body; they take a shorter drive and pull down as well as out; . . ."[23:47] In the actual description of the stroke he wrote:

> . . . The arms are swept down and out in such a manner that after each has described an arc of about one-eighth of a circle the hands will be twelve to fifteen inches below water level. Then the muscles are relaxed, the elbows brought in to the sides, the palms turned flat, and the hands first drawn toward the chest, next thrust out to the original position.[23:48]

McGillvray[37] also advocated a shortened stroke of the arms with the elbows leading in, and he also mentioned the downward path of the arms ending with the hands 15 to 18 inches below the surface.

However, the general pattern from 1925 to 1940 did not follow the lead of Handley. While most authors mentioned a "slight downward pull", they did not mention any specific depth lower than six inches. Riggen[40] is the only author during the 1930's who described a deep pull; twelve inches below the surface. Smith[49] and Reichart and Brauns[39] suggested a slightly shorter pull. The majority advised a pull to the "side horizontal" or "shoulder level" positions.

Several sources(48; 25; 18; 2) recommended drawing the elbows in to the sides. The Boy Scout aquatic manual(5), in 1938, was the first source, however, to advocate the use of the elbows to lead the hands inward as Sinclair and Henry(46) had suggested in 1893. Jarvis(27), Hawley(24), Kiphuth(31) and Forsyth(17) described strokes very similar to the one described in the Boy Scout manual.

Torney, in 1950, and Madders(34), in 1957, described a downward pull and a bent elbow recovery similar to Handley's stroke of 1918. Torney's description is quite complete.

> To begin their pull, the arms rotate from palm down position to bring the little fingers toward the surface and to face the palms obliquely outward and downward. Continuing their pull, the arms remain fully extended as they press sideward and slightly downward to a depth of not less than 4 inches and not more than 16 inches. Completing their pull, the arms assume partial flexion at the elbows when the hands are halfway to the shoulder line and are drawn toward the ribs.
>
> . . . .
>
> As the elbows press to the sides at the completion of the arm pull, the hands circle downward and inward to a position in front of the chest, and the wrists turn to face the palms downward; from this point the arms extend forward into the glide position.(52:116-117)

One quite different description of the pull and the first part of the recovery was presented by DeWitt, in 1953.

> As the drive begins, the hands follow an arc out, back, slightly downward and away from the center line of the body. . . . When the arms have almost completed a half circle and form an inverted V, the drive is completed and the recovery should start. The hands are brought in by flexion of the arms at the elbows until the palms of the hands are brought together just even with the solar plexus.(13:352)

Writing in the 1960's presented a variety of all of the earlier styles.

Ryan and Ryan[43], Vannier and Poindexter[53], McAllister[36], Higgens, Barr and Grady[26], Juba[28] and Burke and Smith[8] described horizontal or slightly downward strokes, usually calling for the elbows to lead in to the sides when the arms reached shoulder level. Garstang[20] and Russo, Jordan and Matheson[42] suggested a shortened arm stroke but did not give any indication of the depth of the pull.

Armbruster, Allen and Billingsley[3] again took exception to the general rule. They advocated a pull down to 16 inches below the surface while the arms were still ahead of the shoulder line. From there they discussed two different methods of recovery. One called for the elbows to draw the hands in and the other called for the hands to pull inward under the elbows and draw the upper arm after them. In either case the hands were to maintain pressure on the water until they came together under the chin. From there the hands extended on a upward plane until nearly fully extended and then took a downward course so the body slid over the water.

Development of Coordination

There appeared to be considerably less disagreement concerning the coordination of the breast stroke than there was about either the arm or leg styles. Sinclair and Henry, in 1893, gave a rather concise description of a pattern of coordination commonly in use today.

> 1. Steadily incline the body to a horizontal position with the arms and legs closed and extended, palms downward, the feet outward, the head inclined backwards, the back hollowed.
> 2. Bring the arms backward . . ., and as the hands are brought to the front of the chest draw the legs upward.

> 3. Then quickly kick out the legs, blending Nos. 2 and 3 leg actions into one, and as they are extended shoot forward the arms. When the arms are fully extended the legs will be closed and the body will sensibly travel by the impetus gained.(46:76-77)

Fletcher(15) apparently agreed with Sinclair and Henry's method but did not give any organized listing of coordination.

Kellermann and Handley, each of whom wrote in 1918, described a different method. Kellermann believed that the power phases of the arms and legs should occur at the same time.

> It will be very easy for you to combine the movements if you will remember that as the hands shoot out straight ahead, simultaneously with this movement, the legs are drawn up and as the hands turn and plough the water, the legs are kicked away from the body.(30:64)

However, Kellermann suggested what she termed a "slight modification" of that form.

> By this method you will shoot the arms out in front of the chin as the legs are drawn up beneath the body. Now hold the hands outstretched and slightly turned up as the legs kick vigorously back.(30:64)

The comments made by Handley were brief but seemed to describe the same style adopted by Sinclair and Henry. "The legs should be set in motion as the arms finish their pull. . . . For the stroke to be perfectly timed the closing of the legs should occur as the arms attain full reach ahead, . . ."(23:48)

From 1918 until the present authors described what appeared to be adaptations of the stroke advocated by the earlier authors. The description given by Sheffield and Sheffield is an example of the commonly accepted co-ordination.

> Count 1. Inhale while you pull the arms sideward and hold the legs together.

Count 2. Exhale while you bring the hands to the chest and bend the knees outward.
Count 3. Extend the arms forward while you force the legs back and together.(45:114)

There were a few exceptions, however. Hawley(21), Lukens(33), and Torney(52) recommended executing the power phase of the legs when the arms were already in glide position. This agreed with the alternate method suggested by Kellermann. Barnes(4), Smith(49), Shaw, Troester and Gabrielsen(44) and DeWitt(13) timed the three counts of the kick with the three counts of the arm stroke, beginning the leg recovery with the pull of the arms and extending the legs sideward as the arms bent in toward the sides. Madders(34) would start the recovery of the legs during the arm pull also, but suggested slowing the movement so that it was not completed until the arms were ready to extend forward, when the entire power phase of the kick was executed. The Boy Scout manual(5) contained a similar description. As was the case with the leg and arm strokes, most of the exceptions occurred during the 1940's and 1950's.

In the 1960's the same pattern held true. The majority agreed with Sheffield and Sheffield(45). Ryan and Ryan(43), McAllister(36), and Forsberg(16) were the exceptions to the general rule. They followed the example of Barnes. Forsberg shows the difference clearly.

Stage 1. Arms stretching out ahead and legs snapping shut from a V position behind. Breath being expelled.
Stage 2. Arms sweeping back strongly and evenly. Breath being taken. Legs drawing gently into sitting position.
Stage 3. Hands coming into praying position in front of face. Legs pushing smartly into open V position. Breath being held.(16:48)

II. RELATED RESEARCH

Several methods have been used to analyze swimming strokes. Karpovich[(66)] did one of the earliest performance analysis studies in 1930. The purpose of the study was to analyze the fluctuation of speed in the front crawl and breast strokes. An apparatus was developed which would produce a graphic record of the speed variances within the stroke. This earliest "natograph" was arranged so that the length of a line leading to the swimmer and the time in one fifth seconds were simultaneously recorded on a graph. From this the speed of the stroke could be determined. Karpovich concluded that the crawl stroke was a faster stroke due, apparently, to the more constant rate of speed maintained. It was also found that the breast stroke kick contributed more power to the stroke than did the arms. The glide period of the breast stroke was actually faster than the recovery period, thus; the arm stroke had a faster starting pace than the kick, making it appear more powerful than it was.

Alteveer[(71)] did another study using the natograph some years later. His study analyzed the breast stroke, butterfly stroke, crawl and back crawl. The individual parts of each stroke were analyzed in an attempt to determine the cause of the fluctuations in speed. The findings concerning the breast stroke were quite similar to those found by Karpovich. The chart of the speed of a fast breast stroke formed a single peak beginning with the kick and reaching the highest point in the middle of the arm pull and then dropping with the beginning of the leg recovery. A slow breast stroke showed two peaks. There was a slight drop between the kick and the arm pull. The back crawl and crawl produced the most uniform speed levels.

DeVries[60] also investigated the velocity change within a stroke. He suggested the use of the ratio of maximum to minimum velocities as an index of stroke efficiency. DeVries studied the dolphin stroke by means of underwater photographs of the swimmer. Motion pictures were taken against a grid placed on the opposite tank wall. The faster of the two swimmers used as subjects did have less difference in velocity. DeVries felt that further study was necessary using more subjects and more cycles of the stroke before conclusions could be reached.

In a further attempt to analyze swimming strokes, Karpovich[67] examined the water resistance of the human body. He constructed an apparatus called a resistograph, which towed swimmers through the water by means of an electric motor. The tension of a rope leading to the subject, the revolutions of the drum around which the rope was wound, and the time in twentieths of a second were all recorded on a kymograph. Karpovich found that body area alone could not be used to determine resistance because skin friction, eddy resistance and wave making resistance also contributed to the total resistance. Body position was found to be important as the resistance increased with the sine of the angle of inclination. Resistance was found to be greater while trying to attain a certain speed than when maintaining that speed. A formula for figuring body resistance was developed from the results of this study.

	Skin Surface Area in Square Feet	Formulae for resistance in pounds (V = velocity in feet per second) Prone Glide	Back Glide
Men	24-19	$.65V^2$	$.75V^2$
Women and Men	19-16.5	$.55V^2$	$.6V^2$

(67:27).

Two years after this discovery Karpovich(64) attempted yet another approach to the problem of analysis of swimming strokes. He examined the relative values of the arm and leg movements to the whole stroke. The subjects swam sixty feet at maximum speed using first the arms only then the legs only and finally the whole stroke. Karpovich found that the square of the whole stroke was equal to the sum of the squares of the arms alone and the legs alone. He also prepared a table for prediction of speeds based on the above information.

Slack(77) did further study in 1957 using the method developed by Karpovich to evaluate the speed and efficiency of the crawl with and without the use of foot flippers. She wished to see if the Pythagorean Theorem as described above would apply to the crawl when flippers were used on the feet. She was also interested in the changes which might occur in the percentage of speed contributed by the legs and arms when flippers were used. Results showed that the Pythagorean Theorem did apply. Actual times of 85.92% of the subjects were within 1.0 seconds of the estimated times when flippers were used. The percentage of contribution of the arms and legs to the whole stroke did change, becoming more nearly equal.

Alley[56] developed a device for studying the resistance and propulsive force of swimming strokes which was a little different from the one used by Karpovich. An electric motor was used to drive a pulling and releasing device. A kymograph was attached to record the amount of force exerted beyond that required to overcome water resistance or to record the drag that the body exerted on the pulling rope. Alley studied two types of crawl arm strokes and two types of flutter kicks. He found the normal stroke superior to any combination of the bent arm pull or short kick at all velocities tested. The normal kick was superior to the short kick and the normal arm stroke superior to the bent arm stroke at all velocities.

The primary purpose of a study by Counsilman[58] was to compare the propulsive forces of a continuous and a glide arm stroke for the crawl. Drag was measured in several velocities and various positions. The results showed clearly the influence of body inclination and the bow wave as the drag curve leveled when the feet began to rise and then increased again as a wave was developed by the head at even higher velocities. The continuous stroke was shown to create more force, more speed and less fluctuation of velocity than the glide stroke.

Thrall[78] used a similar apparatus to analyze the effect of the size and shape of the feet on the flutter kick. Similar results were found on the measurement of drag. Both body position and bow wave effected the measurements. The normal kick was found to be superior to a feathered kick and the use of fins raised the means of free swimming speed and effective propulsive force. Narrow fins were superior to the wide fins.

Barry[72] used the apparatus developed by Alley to examine two styles of arm stroke and two styles of leg stroke used in swimming the breast stroke. A straight arm and bent arm entry into the water were used to differentiate the arm strokes and a frog and dolphin kick were designated as the two kicks. He found that the straight arm entry and the dolphin kick were superior to the others. The dolphin kick produced a "smoother" stroke.

Cake[73] analyzed the effectiveness of two styles of frog kick in terms of force, speed and economy of movement. The measuring apparatus was an adaptation of the one developed by Karpovich. The kicks were designated as wedge action and circular arc whipping action. The experienced group of swimmers developed significantly greater force, used fewer kicks to travel seventy five feet and had a faster time for seventy five feet with the circular arc whipping action. An inexperienced group was divided into two groups and one was taught each kick. No significant differences were found between the two groups. The wedge kick did give slightly better time and produce slightly more power.

One of the earlier studies, which used measures of respiration, was done by Cureton[59] in 1930. A pneumograph was used to record movements of the chest and abdomen as the subject breathed. Subjects were tested on land, floating in the water, and swimming various strokes at different speeds. Immersion caused irregular breathing. Breathing was affected by temperature of the water and the manner of entering the water. When swimming, movements of the stroke itself interfered with respiration. Pressing down with the arms and vigorous action of the legs lowered vital capacity. Cureton stated that, "proper mechanics contribute to success but are secondary to efficient respiration."(59:68)

Aycock, Graaff and Tuttle(57) used a somewhat different method to study the respiratory pattern of swimmers. A tube lead directly from the nostrils to a tambour with a pen attached. U shaped electrodes were taped to the lips to close an electrical circuit when the mouth was closed. The results showed that, even if taught a specific breathing method, each individual developed his own pattern. As the stroke rate increased the general pattern remained the same but the maintained pressure phase of the breathing was shortened.

Karpovich(65) also found that the arm and leg motion interfered with good respiratory efficiency, but he pointed out that respiratory movements also decreased speed. Breathing demanded movement of certain muscles of the chest and abdomen which needed to be stabilized for most effective swimming movement.

Karpovich and Le Maistre(68) did another study attempting to see if the Sargent method of predicting track running could be applied to breast stroke swimming. The breast stroke was chosen because of the large fluctuations in speed. One subject swam at various rates of speed, holding his breath during the swim and breathing into Douglas bags at the end. The prediction method used by Sargent can be applied to the breast stroke. The feet per second and the oxygen debt must be known from a distance swim and the oxygen intake during swimming must be found from a stationary swim at the same velocity.

Van Huss and Cureton(70) gave a fifty-two item battery of tests to determine the interrelationships and relative importance of energy metabolism measures, cardiovascular tests and practical swimming tests to 100-yard and 440-yard swimming performances. The gross oxygen debt was found to be the metabolic measure most closely related to all-out performance. The practical swimming tests were most closely related to the actual 100-yard or 440-yard swims. The capacities measured by the gross oxygen intake and the 100-yard drop off test were more closely related to the 100-yard than the 440-yard performance. Capacities measured by the gross oxygen intake combined with a 60 foot test using the legs only and a 24 foot timed glide were more closely related to the 440-yard than the 100-yard swimming performance. The total battery related better with the 440-yard than the 100-yard performances.

Fox(75) was interested in comparing the difficulty and the speed of open and closed swimming turns, using respiratory measures. The speed was recorded from the time the swimmer passed a line 3 feet 10 inches from the side of the pool until the feet left the side of the pool following the turn. The oxygen debt measures were taken following a seventy foot swim without breathing. Gas was collected for fifteen minutes and analyzed by the Haldane method. Fox found no difference in the energy cost of the two turns, but the closed turn was significantly faster than the open turn.

Karpovich and Millman[69] did a study to determine the amount of energy spent in various swimming strokes done at different speeds. The crawl, side stroke, breast stroke and butterfly stroke were included in the study. The breath was held during the swim and collected for twenty to forty minutes following the swim. The amount of energy used was calculated from the oxygen debt. Energy expenditure of the crawl was found to be roughly proportional to the square of the speed. The relative energy cost of the strokes depends on the rate of speed. The energy cost of the crawl, back crawl, breast stroke and side stroke are always in that order respectively. The butterfly is less costly than the side stroke at three feet per second and less costly than the breast stroke at speeds greater than three feet per second.

Fox[62] did a study on power tests from a different viewpoint. The distance covered by a specific number of strokes proved to be good test of swimming ability. The test was done by college students who swam the front crawl and side strokes. The test was begun from a dead start. The feet were supported by a rope which was dropped at the starting signal. The subject completed six strokes and measurements were taken from the position of the ankles at the start to the position of the ankles at the end of the fifth complete stroke. Distance was read from tape markers on the pool deck. The reliability of the test on the side stroke and front crawl was .97 and .95 respectively. Face validity was assumed. Fox stated that, "preliminary work with the test on the back crawl and breast stroke, and elementary back stroke indicate that the test will probably be reliable and valid for these also."[62:237]

Shute[76] used another test of the power of individual movements of the crawl, breast stroke and elementary back stroke. A spring scale was secured to a pillar and a nylon rope was attached from the scale to the swimmer. As the swimmer pulled against the rope the force was registered on the scale. The purpose of the Shute study was to determine the amount of power contributed by arms and legs independently as related to the total strokes. Results showed that the arms contributed more of the force on the crawl and the legs produced more power for the elementary back and breast strokes.

Ford[74] studied teaching methods applied to the whip and wedge kicks used in the breast stroke. Two methods of teaching the whip kick were used. They were compared to each other and to a standard method of teaching the wedge kick. No differences were found in the learning of any of the three styles of kick at the end of nine lessons.

III. SUMMARY

Many of the studies done in aquatics are concerned with the fluctuation of speed and the resistance of different strokes and body positions. Most sources seem to agree that the least fluctuating strokes are the fastest. Tests of resistance tend to show that accelleration to a given speed causes more re-sistance than the maintaining of that speed. It has been suggested that the ratio of maximum to minimum velocity within a stroke cycle be used to indicate the efficiency of the stroke. Comparisons of strokes in this manner usually show the crawl stroke far ahead and the breast stroke farther down the list.

Studies comparing the contributions of arms and legs to the total propulsive force and speed of coordinated strokes have also been done. It seems apparent that there are certain optimum correlations between the arm and leg strokes of swimmers who excel.

Respiratory studies have been done which compare the breathing patterns of swimmers. Authorities seem to agree that breathing is a most important part of swimming efficiency. Some consider it to be more important than the mechanics of other parts of the stroke. It has been shown that swimming interferes with good respiratory functioning and that respiratory functioning interferes with good swimming mechanics.

Different strokes and techniques of swimming have been compared in various ways. The mechanical analysis of strokes speaks of the efficiency of the stroke in terms of propulsive power and drag. The study done by Cake[(73)] on two styles of frog kick is one of this kind. She found a circular arc whipping action kick to be more powerful. Respiratory measures have also been used to compare strokes. The comparison of the energy cost of five different strokes was done by Karpovich and Millman[(69)]. Again the crawl was found to use less energy and the breast stroke was slower.

There is still great need for more research in the area of aquatics. Much of the information accumulated to date is applicable to the areas of recreational swimming as well as in the search for faster competitive strokes.

CHAPTER IV

PROCEDURES

The purpose of this study was to compare four styles of breast stroke swimming in order to determine if one style could be shown to be more efficient for use by recreational swimmers.

I. SUBJECTS

The subjects were freshmen and sophomore women enrolled in four intermediate swimming classes at the University of North Carolina at Greensboro. Participation in the study was determined by enrollment in the classes. Intermediate classes were chosen because the breast stroke is a regular part of the instruction and because the skill level was considered to be most comparable to that of general recreational swimmers. The classes met twice each week for fifty minute periods, of which approximately thirty to thirty-five minutes were spent in the water. The classes were taught by two instructors and two graduate assistants of the Department of Health, Physical Education and Recreation. The particular stroke taught in each class was determined by the instructors, who drew for their assignments. The class schedule, stroke assignments and number of students are shown in Table I.

TABLE I

CLASS SCHEDULE, STROKE ASSIGNMENTS
AND NUMBER OF STUDENTS

Class	Time	Days	Stroke	Number Students
Class 1	9:00	Monday Wednesday	Horizontal Pull Whip Kick	10
Class 2	11:00	Monday Wednesday	Diagonal Pull Whip Kick	11
Class 3	11:00	Tuesday Thursday	Diagonal Pull Wedge Kick	15
Class 4	2:00	Tuesday Thursday	Horizontal Pull Wedge Kick	17

II. CLASS INSTRUCTION

A meeting of the four instructors preceded class meetings at the beginning of the semester. The purpose and procedures of the study were explained and the objectives of the swimming classes were discussed. The objectives of the classes as related to this study were (1) to teach one of the breast stroke styles in each class (2) and to attempt to bring all classes to a similar level of proficiency at the end of the six weeks of instruction.

A copy of the analysis of both arm strokes and both leg strokes was presented to all instructors for study and comparison. Discussion and dry land demonstration of each helped to clarify and emphasize the differences between the actions. The major differences between the leg strokes were the positions of the knees during the recovery and the path of the feet and the opening of the legs on the second movement. The wedge kick called for a wide spread of the knees with the legs remaining in a horizontal plane. The whip kick required a downward bend of the knees which remained hip distance apart. The feet were to be directly over the knees. The second movement of the wedge kick was a wide opening of the legs by straightening the knees. The second movement of the whip kick was a rotation at the hip joint. The legs straightened without moving the knees further apart than they were on the first movement resulting in a very narrow spread of the legs. The last part of the two kicks was essentially the same.

The major differences in the arm stroke were the depth of the hands and the bending of the elbows on the pull and the action of the hands and elbows on the recovery. The horizontal pull was made just under the surface and only very slightly downward while the diagonal pull was about sixteen inches under the surface. The arms were held straight on the horizontal pull but the elbows were bent nearly ninety degrees on the diagonal pull. The recovery of the horizontal pull originated in the elbow movement inward. The diagonal recovery was made by the hands first as they came inward and upward to the chest position. The final extension was very much the same in both strokes. A complete analysis of each phase of the stroke is included in the Appendix.

A preliminary course outline had been prepared and was presented to the instructors for their approval in order to assure similar experiences for all students. The outline attempted to fit the instruction of the breast stroke as nearly as possible into the regular intermediate instruction; however, there were some changes necessary to meet the objectives of the class for this study. Teachers were asked to use the same style kick which they would later use for the breast stroke when teaching or reviewing the elementary back stroke. Side stroke instruction was postponed until after the testing had been completed in order to avoid any danger of the scissors kick influencing the form of the breast stroke kick. The breast stroke was introduced during the first lesson of the third week and practice was continued during a portion of each class period for the remainder of the course. A copy of the course outline may be found in the Appendix.

A distance swimming requirement was added to each lesson because of the effect endurance might have on the oxygen consumption test. Thus,a closer control was possible on the amount of swimming and accompanying endurance build up for each class. Recreational swimming during the evening and week-end swimming periods was left up to the individual student. They were encouraged to swim if their skills or endurance were low or to make up absences from class, but they were asked not to swim beyond the required endurance distances.

The instructors agreed on basic instructional methods in an effort to assure closer range of skill level in the four classes. Shallow water drills were used for the arm stroke and bracket drills were used for the leg stroke. No land drills or artificial supports were used. Frequent visits were made to the various classes. The teachers were asked to report progression of the breast stroke skills in order to keep the classes at a similar level. Additional practice or instruction time was necessary in some classes, while other classes devoted more time to skills such as diving or safety techniques. The class outline was planned to allow for this flexibility. A copy of the outline may be found in the Appendix.

III. MEASUREMENTS

Measurements were taken to compare the four classes in skill level, power of the complete stroke, and oxygen increase after swimming the stroke. All testing was done following six weeks of class instruction. The skill rating and power test were administered during the second class period of the seventh week and the oxygen test was given by individual appointment during the seventh week.

Skill Rating

Judges for the skill rating were the four instructors and the director of the physical education swimming program. These judges were selected because they were already familiar with the study and with the four styles of the stroke. The judges worked in teams of three. One instructor and the swimming director were members of all four teams. The instructor of the class being rated served as the third judge. Another instructor filled in as the third judge when the class taught by the regular judge was rated.

A detailed analysis of each of the combined strokes, with special emphasis on the distinguishing points, was prepared for the aid of the judges prior to the testing. The analysis contained subdivisions describing the arms, legs, coordination, breathing, and body position for each stroke. Along with the analysis, a copy of the four point rating scale was given to the judges. Each skill level contained the same five subdivisions as the analysis, but these were developed in such a way that the terminology could apply to any of the different strokes. The skill levels in the rating scale were designated as excellent, good, fair and poor. A short descriptive sentence of each level was included on the score sheet during the actual rating session. The score sheet also included a space to indicate deviations in style and a space for comments by the judges. The subject was eliminated from the study if the style used was not the one taught in that particular class. Copies of the analysis, rating scale, and score sheet may be found in the Appendix.

Power Test

The power test, used to compare the forces of the complete stroke, was an adaptation of a test developed by Fox[62]. The original test had been developed and tested on the crawl and side strokes. The test appeared to be more reliable for the glide stroke than the crawl. Fox reported that additional work with the breast stroke indicated that it would be a satisfactory measure for this stroke also.

Tape markers were placed on the deck of the pool at three foot intervals with the footage written on the tapes. Measurements and tapes began at the first five foot pool marker at the shallow end of the pool and continued for sixty feet. Markers were placed three feet apart rather than five feet, as recommended by Fox, as an aid to objectivity.

The swimmer assumed a face float with her feet supported across the arm of the next swimmer in line. The arm was held bent at the elbow so that the swimmer's ankles could rest across the top of the forearm about a foot under the surface. The ankles were held in line with the first tape marker. The manual starting method was used in preference to the rope system described by Fox to give greater control over the position of the subject.

On the signal "Ready", the swimmer placed her face in the water and her arms in the glide position. On the signal "Go", the supporting arm was dropped from under her feet and she began to stroke. The subject was asked to swim at least six strokes. Measurements were taken from the position of the ankles at the end of the glide before the pull for the sixth stroke. Scores were recorded to the nearest foot, and the best of three trials was considered the final score.

Instructions and a demonstration of the starting method were given and subjects were permitted to practice two or three times while waiting their turn. Swimmers were instructed to use only the stroke they had been taught in class.

The skill ratings and power test were given at the same time. Subjects were required to swim the complete length of the pool for the first two power trials. Judges rated the swimmers during the first trial and observed the second trial as confirmation of the rating. Scores were the total of the ratings of the three judges. The third power trial required only six strokes. After each trial the subjects returned to the shallow end walking along the deck opposite the judges.

Oxygen Uptake

A closed circuit respirometer of the Benedict-Roth style, manufactured by Warren E. Collins Corporation, was used to measure oxygen uptake. It consists of an inverted, water-sealed bell containing oxygen with a pen arranged to record the movements of the bell on graduated kymograph paper. As the subject breathes through the breathing tubes, the pen records a measure of the oxygen volume passing to and from the bell. The accumulation of carbon dioxide from the expired air is prevented by passage of the air through a soda lime canister. As the oxygen in the bell diminishes the pen records a measure of the oxygen uptake.

Readings of the oxygen uptake per minute were taken directly from the kymograph paper and corrected to the volume occupied by dry gas at 0^{o} C. and 760 mm. pressure[9]. In order to make the correction, records were kept of the gas temperature and the barometric pressure readings at the time of each testing. The temperatures of the pool water and the room air were also taken. The pool water was kept at a constant temperature of eighty-two degrees and the air temperature was kept as nearly as possible at eighty-four degrees.

Subjects reported to the pool in tank suits but without taking showers. Fifteen minutes of rest were taken seated on the side of the pool with the feet supported in the overflow trough. During this time the testing procedure was explained and the purpose of the study was discussed. Appointments were so arranged that one subject could rest as the preceding one was being tested. When the resting time had passed, the subject lowered herself as quietly as possible into the water and submerged to shoulder level. A few seconds were allowed for her to become accustomed to the water temperature. Moving as quietly as possible she approached the machine and inserted the mouthpiece between the teeth and lips, biting on the tabs. The subject stood erect; one hand supported the breathing tubes and the other pinched the nostrils closed with thumb and forefinger. The slipperiness caused by the water made use of nose clamps difficult and caused a lag between the swimming and the post breathing test. It was not desirable to leave the clamps on during the swim because of interference with the normal breathing pattern.

The valves of the breathing tubes were turned to room air and the subject was given time to familiarize herself with the machine before the first test was begun. When she indicated that she was ready, the valves were closed and the machine switched on. The machine was stopped at the end of three minutes. The subject removed the mouthpiece and pushed off from the side to begin the fifty yard swim. Two lengths of the pool were swum and the swimmers were allowed to touch and push off from the deep end.

Immediately upon returning to the shallow end subjects swam to a position directly in front of the machine. The subjects again inserted the mouthpiece and another three-minute recording was made. Normally only one breath was taken after the swim and before the mouthpiece was in place and the machine operating.

The subjects were allowed to submerge and become accustomed to the water before the first oxygen readings so that conditions before and after the swim would be as similar as possible. Both tests were taken with the subject standing in the water so that any time lag or extra exertion while climbing from the pool after the swim would be eliminated.

A distance of fifty yards was selected as the length of swim after observing the classes. Most students were capable of covering the distance without undue strain. The swim was long enough to cause some observable changes in respiration pattern.

An effort was made to keep the swimming as nearly normal as possible. The directions given to the subjects emphasized that the swim was not a speed contest. They were to swim at the most comfortable speed. It was hoped that the subjects would have found their most comfortable rate of swimming during the endurance swims in classes. All the classes had been taught the standard rhythmic breathing of one breath per stroke. This method was used during the test swimming.

IV. STATISTICAL TREATMENT

The data collected were used to compare the four classes in skill, power and oxygen uptake. An analysis of variance was used in the cases of skill and power. No pre-treatment tests were possible in these situations, as subjects had no knowledge of the necessary skills. The availability of pre-treatment tests of oxygen uptake made the use of an analysis of covariance possible in that case.

The reliability of the power test was determined through use of the Pearson Product Moment Correlation method. The objectivity of the skill rating was determined by both the Spearman Rank Order and the Pearson Product Moment methods.

The relationships of the various test scores to each other were investigated by Pearson Product Moment Correlations.

CHAPTER V

PRESENTATION AND INTERPRETATION OF DATA

The data reported in this chapter were collected and treated in an attempt to study statistically the power and oxygen uptake of four styles of breast stroke. The subjects were fifty-three freshmen and sophomore women enrolled in intermediate swimming classes. The number of subjects treated in each statistical computation varied because of absences during the testing sessions. The scores used were the sums of three judges ratings of skill, the best of three power trials, and the raw scores of pre and post swimming oxygen uptake per minute. The data will be presented in four sections: skill ratings, power test, oxygen uptake and interrelationships of the three tests.

I. SKILL RATINGS

Analysis of Variance

The tests of power and oxygen uptake were likely to be closely related to and influenced by the skill level of the various classes[29, 63]. An analysis of variance of skill ratings was used to determine the similarity of the classes in skill level. The original four point scale of 0-3 was expanded to give a range of 0 to 9 points by totalling the original three ratings. As the skill rating was used to determine similarity of classes only those subjects having the skill score and the power or oxygen were used for each set of correlations or analyses. The required

F value for those having both skill and power scores was 2.84. The obtained value was 1.80 (See Table II) and the conclusion was made that there was no significant difference between any of the four classes. The required F value for the groups having both skill and oxygen uptake scores was 2.87. The obtained F value was 2.25 (See Table III) and again the conclusion was drawn that there was no significant difference between any of the groups. It was assumed that any differences found between the classes in power or oxygen uptake would not be likely to be caused by differences in skill level of the classes.

Judges Intercorrelations

Spearman's method of rank difference correlation was used to determine the consistency of the judges ratings within any one class. The Pearson Product Moment method was used to measure the consistency of judges over the entire four classes. Low correlations, below .70, indicated that the thinking of the judges was not consistent with the rating scale or not consistent with each other.

The range of correlations found in the group taking the power test was from .54 to 1.0. (See Table IV.) There were five correlations below .70. There was no apparent consistency in the proportion of highest or lowest correlations distributed among the judges. The correlations which did not include subjects who had no oxygen scores were somewhat lower, possibly because the smaller number of subjects magnified the influence of slight inconsistencies. The range of correlations was from .46 to 1.0. (See Table V.) There were six correlations lower than .70. Again, there was no apparent pattern of high

TABLE II

MEAN SKILL RATING SCORE OF THE FOUR CLASSES AND THE ANALYSIS OF VARIANCE INCLUDING ALL AVAILABLE SCORES

Classes	N	S.D.	Mean
1	9	3.09	3.78
2	10	2.32	3.80
3	14	2.56	5.00
4	11	2.41	6.18

Analysis of Variance

Sources	SS	df	MS	F*
Groups	40	3	13.30	1.80
Within Groups	296	40	7.40	

*$F_{05}(3, 40\ df) = 2.84$

TABLE III

MEAN SKILL RATING SCORES OF THE FOUR CLASSES AND THE ANALYSIS OF VARIANCE NOT INCLUDING SUBJECTS LACKING OXYGEN UPTAKE SCORES

Classes	N	S.D.	Mean
1	8	2.95	4.25
2	9	2.40	3.66
3	11	1.93	5.91
4	11	2.41	6.18

Analysis of Variance

Sources	SS	df	MS	F*
Groups	43.86	3	14.62	2.25
Within Groups	226.50	35	6.47	

*$F_{05}(3, 35\ df) = 2.87$

TABLE IV

INTERCORRELATIONS OF JUDGES SKILL RATINGS
INCLUDING ALL AVAILABLE SCORES*

Class 1	Judge 2	Judge C
Judge 1	1.0	.54
Judge 2		.54
Class 2	Judge 2	Judge B
Judge 1	.76	.87
Judge 2		.79
Class 3	Judge 2	Judge A
Judge 1	.66	.72
Judge 2		.69
Class 4	Judge 2	Judge A
Judge 1	.80	.71
Judge 2		.83
Total Group**	Judge 2	Judge 3***
Judge 1	.79	.69
Judge 2		.73

*Judges 1 and 2 served on all teams, Judge A served on two teams and Judges B and C each served on one team.

**Pearson Product Moment method of correlation was used for the four classes combined.

***Judges A, B, and C were considered as one.

TABLE V

INTERCORRELATIONS OF JUDGES SKILL RATINGS
NOT INCLUDING SUBJECTS LACKING OXYGEN UPTAKE SCORES*

Class 1	Judge 2	Judge C
Judge 1	1.0	.46
Judge 2		.46
Class 2	Judge 2	Judge B
Judge 1	.79	.88
Judge 2		.90
Class 3	Judge 2	Judge A
Judge 1	.55	.59
Judge 2		.54
Class 4	Judge 2	Judge A
Judge 1	.80	.71
Judge 2		.83
Total Group**	Judge 2	Judge 3***
Judge 1	.78	.63
Judge 2		.92

*Judges 1 and 2 served on all teams; Judge A served on two teams and Judges B and C each served on one team.

**Pearson Product Moment method of correlation was used for the four classes combined.

***Judges A, B, and C were considered as one.

or low correlation distribution among the judges. No one judge could be said to have had a greater influence on the correlations.

Practice rating sessions and demonstrations of the strokes in the water may have raised the correlations for both sets of ratings.

II. POWER

Analysis of Variance

Differences in power scores among the groups were determined by an analysis of variance of those subjects who had both skill and power scores. The obtained F value was 4.01, (See Table VI) which was above the 2.84 value required for significance at the 5 per cent level.

Investigation of the relationships between the various classes showed significant differences between Class 4 and each of the other three classes. This would indicate that Class 4, using the wedge kick and horizontal pull, had superior power to each of the other classes. The other classes, each using a different stroke, were not significantly different from each other.

Reliability Coefficient

Reliability of the power test was determined by a Pearson Product Moment correlation of the best with the second best trials for all classes combined. The r obtained for all available power scores was .970 and the r for the subjects who had both skill and power scores was .974. (See Table VII.) The power test for this group proved to be very reliable. The correlations were comparable to those found by Fox[62] for the side stroke and front crawl.

TABLE VI

MEAN POWER SCORES MADE BY THE FOUR CLASSES, THE ANALYSIS OF VARIANCE AND SUBSEQUENT "t" VALUES NOT INCLUDING SUBJECTS LACKING SKILL RATINGS

Classes	N	S.D.	Mean
1	9	8.32	21.89
2	10	5.63	24.50
3	14	6.94	24.50
4	11	8.12	32.73

Analysis of Variance

Sources	SS	df	MS	F
Groups	702	3	234.33	
Within Groups	2340	40	58.53	4.01*

Significance of Differences Between Means

Classes	Means	N	"t"
1	21.88	9	.75
2	24.50	10	
1	21.88	9	.80
3	24.50	14	
1	21.88	9	3.15***
4	32.73	11	
2	24.50	10	0
3	24.50	14	
2	24.50	10	2.46*
4	32.73	11	
3	24.50	14	2.67**
4	32.73	11	

*Significant at 5 per cent level
**Significant at 2 per cent level
***Significant at 1 per cent level

TABLE VII

CORRELATION OF THE BEST WITH THE SECOND BEST TRIALS ON THE POWER TEST

	N	r
All Scores	53	.970
Excluding subjects lacking oxygen test	48	.974

III. OXYGEN

An analysis of covariance[38] was used to examine data collected from the oxygen uptake tests. The criterion F was 2.88 and the obtained F on the main evaluation was .029. (See Table VIII.) The null hypothesis was accepted and it was concluded that there were no apparent treatment effects.

TABLE VIII

ANALYSIS OF COVARIANCE FOR OXYGEN UPTAKE TEST NOT INCLUDING SUBJECTS LACKING SKILL RATINGS

Component of Variability		SS	df	V	F
Treatment	(D)	3981	3	1327	.029*
Error	(E_w)	1562946	34	45998	
Total	(E_t)	1567927	39		

*F_{05} (3, 34 df) = 2.88

The lack of a significant F could be accounted for in several ways. The variable considered to have the greatest effect was the lack of an adequate base line on the pre-swimming recording. Examination of the raw scores, (See Table XI in the Appendix) showed an unusually large range of scores. Several students had a slightly lower score following the swim than preceding it. The irregularity and lack of adequate base line indicated that the subjects had not reached a sufficiently steady rate of breathing. They were not adjusted to the machine or to the conditions during the test. Measures were taken in the water in order to eliminate the time lag between the end of the swim and the beginning of the recording and the effort exerted by leaving the pool at the end of the swim; however, this procedure necessitated a change in position from the resting conditions and an adjustment to the water temperature prior to the pre-swimming test. Possibly these adjustments affected the respiration enough to eliminate an adequate base line reading. It is also possible that the emotional factor of anticipation of the fifty yard swim can not be ignored. A pre recording of ten minutes or more would have been desirable to get an adequate base line reading. At the time of planning the study a ten minute recording period was considered impractical in a swimming situation and recordings of three minutes were taken believing that the base line obtained would be acceptable.

The post swimming tests may also have been affected by the lack of adjustment to the machine. The time during the swim, when the machine was not used, may have been sufficient to require readjustment during the second recording. Another factor affecting the final reading was the amount of oxygen breathed during the swim, which was not measured. The rate and depth of breathing during the swim would affect the degree of oxygen debt built up at the end and thus affect the final reading of oxygen uptake. Measures of oxygen uptake during the swim were not taken because of technical difficulties. The apparatus necessary to obtain such measures would have interfered with the natural conditions of swimming and possibly with the stroke patterns of the subjects. This was doubly undesirable because of the fine differences in the strokes and the skill level of the subjects.

The speed of the swimming could also have affected the final scores. Speed was left up to the individual for the same reasons as those mentioned above for not recording during the swim. It was hoped that each subject would have discovered her most economical and comfortable speed during the endurance swimming practice in classes.

IV. INTERRELATIONSHIPS AMONG TESTS

The scores made by all classes combined on each of the tests were related by the Pearson Product Moment Correlation method. The r obtained for the relationship of power to skill rating was .688. (See Table IX.) This was much lower than the correlation reported by Fox[(62)]. The lower coefficient may have been related to the fact that the skill levels of the various classes were found to be similar while the power analysis showed a significant difference between Class 4 and the other three classes. (See Table VI.) This conclusion was supported by the correlations of skill and power for individual classes, (See Table X.) in which

TABLE IX

INTERRELATIONSHIPS AMONG THE SKILL, POWER AND OXYGEN UPTAKE TESTS

	Power	Oxygen Uptake
Skill	.69	.14
Power		.17

TABLE X

RELATIONSHIPS OF SKILL AND POWER FOR INDIVIDUAL CLASSES

Class	N	r
1	9	.71
2	10	.74
3	14	.70
4	11	.46

Class 4 showed the lowest correlation, .46. The other correlations ranged from .70 to .74. The differences between the results reported by Fox and the results found in this study may be due to the different style stroke used by Class 4.

The correlation of the oxygen uptake test with the power and skill tests were very low, .17 and .14 respectively. A higher correlation had been expected in the comparison of oxygen and skill[29]. The correlations may have been higher if the further controls of the oxygen test already discussed in this chapter had been possible.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The purpose of this study was to compare the power obtained and the effort expended by four styles of breast stroke in an attempt to determine if one style were more efficient for use by recreational swimmers of average skill. Fifty three freshmen and sophomore college women enrolled in four intermediate swimming classes were taught four different styles of breast stroke. The classes met twice each week during the study. General class outlines and lessons were the same for all classes. At the end of six weeks each class was given a skill rating to determine the similarity of skill level among the classes. Five judges worked in teams of three. All members were familiar with the study and the different styles of stroke. Treatment of the data obtained by analysis of variance showed no significant skill differences between any of the classes. The consistency of the judges ratings, determined by the Pearson Product Moment Correlation method showed a range of correlations from .69 to .79 for all subjects and a range from .63 to .92 for those subjects who had both power and skill rating scores.

The power developed by each stroke was measured by the distance covered in five strokes. Reliability of the test, determined by correlating the best with second best scores, was found to be .974 for those subjects who also had skill rating scores. An analysis of variance yielded a significant F showing that power differences existed among the classes. Further "t" tests showed that Class 4, using a horizontal pull and wedge kick was significantly superior to each of the other classes.

An indication of the effort expended in swimming each of the strokes was determined by a measure of oxygen uptake previous to and following a fifty yard swim. The F resulting from an analysis of covariance was not significant.

The following results were indicated by the data collected and analyzed:

1. The skill rating was considered sufficiently objective for use as a measure of similarity of the classes. The average correlation between judges ratings on the entire group was above .70.
2. The skill levels of the classes were similar. The analysis of variance showed no significant differences.
3. The power test was reliable.
4. Differences were apparent in the power measures of the classes as indicated by an F significant at the 5 per cent level of confidence.
5. Class 4, using a horizontal pull and a wedge kick produced power scores significantly superior to each of the other classes.
6. Analysis of covariance of the oxygen uptake data showed no apparent treatment effects. Conclusions were not drawn from this data because of the degree of unreliability apparent in the test.

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APPENDIX

GENERAL COURSE OUTLINE

Week	First Day	Second Day
1.		Crawl Float Elementary back stroke Tread General testing of Safety and ability
2.	Floating Flutter kicks front and back Crawl arm stroke Coordinated stroke Treading	Review crawl Add breathing Floating Review treading
3.	Review breathing and complete crawl Introduce breast stroke legs and arms	More complete crawl Review part of breast stroke Coordinate stroke
4.	Review breast stroke and breathing Floating, treading Crawl review	Review whole breast stroke Introduce elementary back stroke legs and arms Coordinate elementary back stroke
5.	Review elementary back Sculling Breast stroke Front crawl	Elementary back Sculling - additional directions Surface dives Review flutter kick on back
6.	Back crawl arms Coordinated back crawl Surface dives review Underwater swimming	Review of back crawl Review of underwater swimming Breast stroke Elementary back stroke

Endurance Swimming

Week

2.	2 lengths front crawl	To be done during the last lesson of each week
3.	3 lengths front crawl 1 breast stroke	
4.	4 lengths front crawl 2 breast stroke	
5.	4 lengths front crawl 4 lengths breast stroke 2 elementary back	
6.	4 lengths front crawl 4 lengths breast stroke 2 elementary back stroke 2 back crawl	

TEACHERS ANALYSIS

Kicks

Wedge Kick

Starting Position

Prone float position, face in the water just above the eyes, arms extended in front of the head, thumbs touching, palms down. Feet together, legs extended, toes pointed, just under surface.

Recovery

legs rotate so soles of feet are touching
as knees bend they spread outward
feet remain together
legs are in horizontal position parallel to the surface
draw feet up as close to hips as comfortably possible

Spread

ankles flex
knees straighten--this will spread feet about 36"
soles of feet press against water in a diagonal outward and backward direction

Snap

legs begin to close and ankles extend just before knees straighten to full extension
legs close to starting position with knees extended

Whip Kick

Starting Position

Prone float position, face in the water just above the eyes, arms extended in front of the head, thumbs touching, palms down. Feet together, legs extended, toes pointed, just under surface.

Recovery

knees bend as feet are drawn up toward hips
knees separate only slightly and feet are in line with or slightly wider than the thighs
feet are at the surface, knees deep
ankles are flexed

Spread

legs rotate so feet are pointed outward
feet are outside knees as feet are spread apart
feet describe an outward and backward arc as knees straighten
soles of feet press against water

Snap

legs begin to close just before full extension of knees
ankles extend
legs close to starting position with legs straight

Arm Strokes

Horizontal Pull

Starting Position

Prone float position, face in the water just above the eyes, arms extended in front of the head, thumbs touching, palms down, just under surface. Feet together, legs extended, toes pointed, just under surface.

Pull

hands turn back to back
hands cupped to hold water
wrists slightly flexed
pull out and just slightly down (about 6")
arms straight

Bend

just before arms form straight line with shoulders the elbows bend and draw upper arms to sides
hands follow elbows in on same plane
hands rotate so little finger lower than thumb and press together and down as come in to meet under chin

Extension

hands rotate so palms down
elbows straighten to starting position
fingers point slightly up and arms move diagonally upward to 3" below surface

Diagonal Pull

Starting Position

Prone float position, face in the water just above the eyes, arms extended in front of the head, thumbs touching, palms down, just under surface. Feet together, legs extended, toes pointed, just under surface.

Pull

wrists flex and rotate so thumbs down
forearms continue downward and outward movement
elbows flex as pull so elbows above hands when hands reach shoulder level
at end of pull hands should be just outside elbows

Bend

hands pull in and up under elbows, thumbs leading and
elbows follow to press upper arm against sides
hands will be pushing water in and down

Extension

palms turn down, fingers pointed forward and slightly up
hands are together as arms extend to starting position
arms move diagonally upward to 4"-6" under surface
move quickly
press down at end of extension

Coordination

Arms and Legs

Arms pull--legs still
Arms recover to bent elbow position--legs draw up to hips
arms begin extension--legs begin spread and snap
force of leg stroke should occur just before arms reach full extension

Breathing

head raises up and forward as hands flex and separate for beginning of pull
chin is at surface of water
inhale in this phase
head reenters water as soon as possible not later than end of pull phase
exhale with head in water and continue through glide
water should be just above eyes throughout stroke

Count

1. pull (of arms)
2. recover (bend)
3. kick (spread and snap)
4. glide (until forward momentum is lost)

Emphasis

1. depth of pull

2. position of hands

3. depth of knees

4. position of feet

5. horizontal position of body

RATING SCALE ANALYSIS

Horizontal pull - Wedge kick

Arms

straight pull to just before shoulder level
pull not more than 6 inches deep
elbows lead in until hands meet under body (chin)
rotation of hands, palms out on pull-in on recovery
thumbs touch on glide

Legs

ankles extended and soles of feet together on recovery
knees near surface of water on bent position
ankles flex for extension
slow, easy recovery and extension
ankles extended for adduction
forceful adduction
feet and legs touch for glide

Breathing

neck hyperextended for lift of head on breathing
head lifted as arms begin pull phase, returns to water before end of pull
chin at surface of water
shoulders remain in water
air exhaled under water

Co-ordination

smooth sweep of arms and legs
arms pull while legs still straight; legs start recovery either as arms bend or just after
arms reach full extension as legs touch following adduction
glide lasts until forward momentum is lost

Body position

water just above eyes
hands just under surface
heels just under surface
force of arms and legs balanced

RATING SCALE ANALYSIS

Horizontal pull - Whip kick

Arms

straight pull to just before shoulder level
pull not more than 6 inches deep
elbows lead in until hands meet under body (chin)
rotation of hands, palms out on pull, in on recovery
thumbs touch on glide

Legs

knees, hips, and feet in line
knees stationary on extension
ankle flexion and leg rotation on extension
forceful extension and adduction
feet and legs touch for glide

Breathing

neck hyperextended for lift of head on breathing
head lifted as arms begin pull phase, returns to water before end of pull
chin at surface of water
shoulders remain in water
air exhaled under water

Co-ordination

smooth sweep of arms and legs
arms pull while legs still straight; legs start recovery either as arms bend or just after
arms reach full extension as legs touch following adduction
glide lasts until forward momentum is lost

Body position

water just above eyes
hands just under surface
heels just under surface
force of arms and legs balanced

RATING SCALE ANALYSIS

Diagonal pull - Wedge kick

Arms

arms bend on pull until form a 90° angle at shoulder level
pull is deep to vertical position of forearm
hands lead in for recovery
hands meet under body
hand rotation, palms out for pull, in for recovery
thumbs touch on extension and glide

Legs

ankles extended and soles of feet together on recovery
knees near surface of water for bent position
ankles flex for extension
slow, easy recovery and extension
ankles extended for adduction
forceful adduction
feet and legs touch for glide

Breathing

neck hyperextended for lift of head on breathing
head lifted as arms begin pull phase, returns to water before end of pull
chin at surface of water
shoulders remain in water
air exhaled under water

Co-ordination

smooth sweep of arms and legs
arms pull while legs still straight; legs start recovery either as arms bend or just after
glide lasts until forward momentum is lost

Body position

water just above eyes
hands just under surface
heels just under surface
force of arms and legs balanced

RATING SCALE ANALYSIS

Diagonal pull - Whip kick

Arms

arms bend on pull until form a 90^{o} angle at shoulder level
pull in deep to vertical position of forearm
hands lead in for recovery
hands meet under body
hand rotation, palms out for pull, in for recovery
thumbs touch on extension and glide

Legs

knees, hips, and feet in line
knees stationary on extension
ankle flexion and leg rotation on extension
forceful extension and adduction
feet and legs touch for glide

Breathing

neck hyperextended for lift of head on breathing
head lifted as arms begin pull phase, returns to water before end of pull
chin at surface of water
shoulders remain in water
air exhaled under water

Co-ordination

smooth sweep of arms and legs
arms pull while legs still straight; legs start recovery either as arms bend or just after
arms reach full extension as legs touch following adduction
glide lasts until forward momentum is lost

Body position

water just above eyes
hands just under surface
heels just under surface
force of arms and legs balanced

RATING SCALE

Classifications

3 points -- Arms
correct form on pull and recovery
smooth sweeping stroke
correct depth and length of pull

Legs
correct form with knees proper depth and width
slow easy recovery
forceful power phase

Breathing
correct timing and
use of neck to lift head

Co-ordination
correct timing
smooth movements
good glide distance
force of arms and legs balanced

Body position
head correct depth
horizontal

entire appearance is one of excellent form and relaxed stroking with power

2 points --Arms
good but no hand rotation
pauses in various positions

Legs
kick in good form but pauses

Breathing
proper coordination but little slow
correct pattern

Co-ordination
proper timing
force of arms and legs not balanced

Body position
horizontal but head too high or low

entire appearance one of good form but slow and weak and some hesitations

1 point -- Arms

form of stroke faulty
no rotation of hands and hands do not meet on recovery
jerky and unnecessary force in extension

Legs

also jerky and unnecessary force in recovery phase
legs fail to meet at end of kick

Breathing

incorrect form and slow because hands used to raise head

Co-ordination

timing is still correct but jerky
power of arms and legs not balanced
shortened glide

Body position

some up and down movement of body in water

entire appearance of stroke is fair. some form errors appear and the body is tense and wasteful of energy. body position is poor.

0 points --Arms

poor form
pull is too deep and either too long or too short
hands do not rotate and
recovery form is incorrect
stroke is jerky and effort is wasted on recovery

Legs

no ankle movement
knees not on horizontal plane
the path is jerky and the kick is incomplete in finish

Breathing

head does not move and the arms force the shoulders and chest out of the water
timing is incorrect and inhale in wrong place

Co-ordination

arms and legs not in proper timing
no glide

Body position

not horizontal

entire appearance of stroke is rushed. there is much up and down movement and much wasted effort, splashing, and breathlessness.

SCORE SHEET

Skill Rating

9:00 MW	Skill	Style	Comments
Cathcart, Carolyn			
Dick, Linda			
Hartsell, Olivia			
Holder, Pam			
Johnson, Debra			
Morton, Mary			
Ritzman, Mary Ellen			
Roberson, Phyllis			
Smith, Lesley			
Van Horne, Janice			

Scale:

3 points --- Excellent form and relaxed stroking with power

2 points --- Good form but slow, weak and with some hesitations

1 point --- Fair form, but with some errors appearing, body is tense and wasteful of energy and in poor position

0 points --- Poor form, and stroke is rushed. There is much up and down movement and wasted effort, splashing and breathlessness.

Style:

If the swimmer uses a form of the stroke other than the one used by the group with which she is swimming place a check (✓) in the column under style opposite her name

TABLE XI

RAW DATA FOR ALL STUDENTS

Subject	Total of three judges ratings	Best of three power trials	Corrected Oxygen Uptake Pre-test	Corrected Oxygen Uptake post-test
1.	3	24	489	503
2.	-	18	635	776
3.	5	37	571	1170
4.	9	27	368	933
5.	3	23	790	959
6.	2	17	466	551
7.	2	20	511	780
8.	1	11	932	1240
9.	9	29	806	820
10.	0	9	---	---
11.	7	29	678	903
12.	5	30	636	774
13.	-	35	536	826
14.	5	25	---	---
15.	6	36	573	1002
16.	3	21	467	522
17.	6	24	508	875
18.	0	22	397	1119
19.	1	18	728	924
20.	4	24	449	645
21.	1	16	1148	1203
22.	2	20	649	706
23.	6	21	629	1035
24.	8	31	428	1056
25.	7	17	777	961
26.	4	22	719	818
27.	-	20	479	508
28.	8	41	510	793
29.	6	23	523	919
30.	9	36	531	629
31.	5	25	536	1156
32.	0	14	---	---
33.	5	25	668	585
34.	4	25	269	678
35.	5	22	---	---

TABLE XI (continued)

Subject	Total of three judges ratings	Best of three power trials	Corrected Oxygen Uptake Pre-test	post-test
36.	1	21	---	---
37.	4	15	726	811
38.	-	41	713	645
39.	8	33	678	1186
40.	4	33	932	1127
41.	9	35	615	587
42.	7	43	475	783
43.	-	24	931	1227
44.	3	39	521	1130
45.	6	25	437	804
46.	9	32	622	1159
47.	-	31	796	782
48.	8	42	382	636
49.	-	20	525	470
50.	8	39	693	736
51.	-	41	685	785
52.	-	42	637	934
53.	2	24	612	484

TABLE XII

CORRECTED OXYGEN UPTAKE SCORES
FOR ALL SUBJECTS

Subjects	Original Scores Three minutes Pre-tests	Original Scores Three minutes Post test	Original Scores One minute Pre-test	Original Scores One minute Post test	Barometric Pressure	Temperature	Correction Factor	Final Score Pre-test	Final Score Post test
1.	1750	1800	583	600	743	30	.838	489	503
2.	2250	2750	750	917	742	28	.847	635	776
3.	2000	4100	667	1367	745	27	.856	571	1170
4.	1300	3300	433	1100	738	27	.848	367	933
5.	2800	3400	933	1133	737	27	.846	790	959
6.	1650	1950	550	650	738	27	.848	466	551
7.	1800	2750	600	917	741	27	.851	511	780
8.	3300	4400	1100	1467	742	28	.847	932	1242
9.	2850	2900	950	967	738	27	.848	806	820
10.	----	----	---	---	---	--	---	---	---
11.	2400	3200	800	1067	755	31	.847	678	903
12.	2300	2800	717	933	739	31	.829	636	774
13.	1850	2850	617	950	760	28	.869	536	826
14.	----	----	---	---	---	--	---	---	---
15.	2000	3500	667	1167	756	29	.859	573	1002
16.	1700	1900	567	633	731	30	.824	467	522
17.	1800	3100	600	1033	742	28	.847	508	875
18.	1400	3950	467	1317	744	28	.850	397	1119
19.	2600	3300	867	1100	744	30	.840	728	924
20.	1600	2300	533	767	745	30	.841	449	645
21.	4100	4300	1367	1433	744	30	.840	1148	1204

TABLE XII (continued)

Subjects	Original Scores Three minutes Pre-tests	Original Scores Three minutes Post test	Original Scores One minute Pre-test	Original Scores One minute Post test	Barometric Pressure	Temperature	Correction Factor	Final Score Pre-test	Final Score Post test
22.	2300	2500	778	833	755	31	.847	649	706
23.	2250	3700	750	1233	731	27	.839	629	1035
24.	1500	3700	500	1233	745	27	.856	428	1056
25.	2750	3400	917	1133	738	27	.848	777	961
26.	2550	2900	851	967	737	27	.846	119	818
27.	1700	1800	567	600	737	27	.846	479	508
28.	1800	2800	600	933	744	28	.850	510	793
29.	1850	3250	617	1083	738	27	.848	523	919
30.	1900	2250	633	750	731	27	.839	531	629
31.	1900	4100	633	1367	737	27	.846	536	1156
32.	----	----	----	----	---	--	---	----	----
33.	2400	2100	800	700	740	30	.835	668	585
34.	950	2400	317	800	738	27	.848	269	678
35.	----	----	----	----	---	--	---	----	----
36.	----	----	----	----	---	--	---	----	----
37.	2550	2850	850	950	756	29	.854	725	811
38.	2600	2350	867	783	739	32	.823	713	645
39.	2400	4200	800	1400	755	31	.847	678	1186
40.	3350	4050	1117	1350	740	30	.835	932	1127
41.	2200	2100	733	700	731	27	.839	615	587
42.	1700	2800	567	933	731	27	.839	475	783
43.	3300	1350	1100	1450	737	27	.846	931	1227
44.	1800	3900	600	1300	760	28	.869	521	1130
45.	1550	2850	517	950	737	27	.846	437	804
46.	2200	4100	733	1367	743	28	.848	622	1160
47.	2900	2850	967	950	739	32	.823	796	782
48.	1350	2250	450	750	738	27	.848	382	636
49.	1900	1700	633	567	739	31	.829	525	470
50.	2450	2600	817	867	739	27	.849	693	736
51.	2400	2750	800	917	745	27	.856	685	785
52.	2250	3300	750	1100	737	27	.849	637	934
53.	2150	1700	717	567	756	29	.854	612	484